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WATER SUPPLY AND WATER QUALITY CONTROL STUDY, NORTH AND MIDDLE FORK SNOQUALMIE PROJECTS, SNOHOMISH RIVER BASIN, WASHINGTON

Federal Water Pollution Control Administration
Portland, Oregon

November 1966

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WATER SUPPLY & QUALITY CONTROL STUDY

UNITED STATES DEPARTMENT OF THE INTERIOR
Federal Water Pollution Control Administration

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WATER SUPPLY AND WATER QUALITY CONTROL STUDY

NORTH AND MIDDLE FORK SNOQUALMIE PROJECTS

SNOHOMISH RIVER BASIN, WASHINGTON

An investigation has been made which discloses a need for storage in Snoqualmie River watershed to meet future water demands in the Seattle urban area. A need for storage for water quality control is not foreseen at this time. Future water requirements and quality projections are based on economic, demographic, and engineering studies.

Prepared at the Request of the

U. S. Army Engineer District, Seattle
Corps of Engineers, Seattle, Washington

By the

U. S. Department of the Interior
Federal Water Pollution Control Administration
Northwest Region, Portland, Oregon

November 1966

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I. INTRODUCTION

A. REQUEST AND AUTHORITY

The District Engineer, U. S. Army Engineer District, Seattle, in a letter dated May 14, 1963, requested the advice of the U. S. Department of Health, Education, and Welfare concerning the needs for storage for water supply and water quality control in the proposed North and Middle Fork Snoqualmie River Projects in the Snoqualmie River subbasin of Snohomish River Basin, near Seattle, Washington, and the value of benefits resulting therefrom.

The water supply portion of this study was made in accordance with the Memorandum of Agreement, dated November 4, 1958, between the Department of the Army and the Department of Health, Education, and Welfare relative to the Water Supply Act of 1958, as amended (43 U.S.C. 390b). The water quality control aspects are considered under authority of the Federal Water Pollution Control Act, as amended (33 U.S.C. 466 et seq.). Responsibility for these activities was transferred from the Department of Health, Education, and Welfare to the Department of the Interior by Re-organization Plan No. 2 of 1966, effective May 10, 1966.

B. PURPOSE AND SCOPE

This investigation was undertaken by the Federal Water Pollution Control Administration for the purpose of advising the Corps of Engineers on the need for and value of storage in the Snoqualmie River Basin for the purposes of municipal and industrial water supply and flow regulation for water quality control. To accomplish this, available data on water uses, waste sources, and water quality were examined, evaluated, and projected. Future needs were projected to the year 2020 with interim projections to 1980 and 2000. An economic base study and forecast of future population and industrial growth was prepared for this purpose and is summarized in this report.

The study area covered in the report is the Snohomish River Basin, excluding the drainage area of the Skykomish River Basin. The Skykomish Basin will be covered separately in connection with the Corps of Engineers Sultan Project investigation.

C. ACKNOWLEDGMENTS

The preparation of this report was aided substantially by officials of the Washington Department of Conservation; Washington Department of Health; Washington Pollution Control Commission; Gray and Osborne, Consulting Engineers; Harstad and Associates, Consulting Engineers; the city of Seattle, Washington; and the U. S. Army Engineer District, Seattle.

The use of information furnished in the references listed in the bibliography is also acknowledged.

II. SUMMARY of Findings and Conclusions

A. SUMMARY OF FINDINGS

1. The proposed Middle and North Fork Snoqualmie River Projects are located in the Snohomish River Basin in northwestern Washington. The Middle Fork Project site is located at about River Mile 10 on the Middle Fork of the Snoqualmie River and the North Fork Project site is located at about River Mile 12 on the North Fork of the Snoqualmie River (see Location Map, back cover).

2. The proposed Middle Fork Project would have a total storage capacity of 129,000 acre-feet of which 120,000 acre-feet would be usable for the purposes of flood control and recreation. The proposed North Fork Project would have a total storage capacity of 155,000 acre-feet of which 140,000 acre-feet is being considered for the purposes of flood control, power generation, recreation, fishery enhancement, water quality control, and municipal and industrial water supply.

3. The average annual runoff of the Snoqualmie River as measured at the gaging station near Carnation, Washington (608 sq. mi. drainage), is 2,734,000 acre-feet (3,777 cfs) for the 32-year period of record (1928-1960). The one-in-ten year low, mean annual flow of the Snoqualmie River near Carnation, Washington, is 2,810 cfs and the mean monthly minimum (August) flow for this recurrence interval is about 700 cfs.

4. The economy of the study area is largely dependent upon transportation equipment manufacturing and service industries in the Seattle vicinity, and pulp, paper, lumber and wood products manufacturing industries in the Everett area. In 1960, the population of the Central Puget Sound study area (King and Snohomish Counties) was 1,107,200.

5. The city of Seattle presently obtains its water supply from both the Tolt River and Cedar River Basins. The presently developed capacity of the Seattle system is 310 mgd. The Cedar River system has a capacity to deliver 220 mgd and the Tolt River system, 90 mgd. Provisions to expand the system to 580 mgd have been made.

6. Municipal and industrial water demands in the Seattle urban area average 125 mgd. The Seattle system in 1963 served 809,000 people, or about 80 percent of the Seattle area urban

population and miscellaneous industries, with a combined average demand of 100 mgd. Average demands for the urban area are forecast to increase to 234 mgd by 1980, 398 mgd by 2000, and 625 mgd by 2020. The Seattle system is expected to serve increasing proportions of the urban areas's demands (80 percent by 1980, 85 percent by 2000 and 90 percent by 2020).

7. Water quality in the upper reaches of the Snoqualmie River watershed is excellent for all uses. The Tolt River supply for example, is treated only by simple disinfection for domestic consumption. Further downstream in the Snohomish River, water quality data indicate some dissolved oxygen and bacterial deterioration (see Appendix TABLE A-1). In the Snohomish River, tidal influence extends to about River Mile 18.

8. At the present time, 7.14 million population equivalents (PE) of organic waste are produced daily in the study area excluding the wastes produced by food processing operations. Of this amount, about 99 percent is attributable to the pulp and paper operations of Simpson Lee Paper Co., located on Ebey Slough, Weyerhaeuser Paper Co., located on the lower Snohomish River, and Scott Paper Co., located on Port Gardner Bay, all in the vicinity of Everett. During the food-processing season, it is estimated that the daily raw waste production in the study area is increased by approximately 181,000 PE.

9. At the present time, 5,740 population equivalents (PE) are discharged to the Snoqualmie River watershed, 37,000 PE are discharged to the lower Snohomish River, and 7,195,000 PE are discharged in the Port Gardner Bay area. Raw waste production in the Snoqualmie drainage area is projected to be 23,400 PE by 1980, 50,500 PE by 2000, and 132,500 PE by 2020.

B. CONCLUSIONS

1. Population of the Central Puget Sound Area (King and Snohomish Counties) is projected to increase to 1,831,000 by 1980, 2,830,000 by 2000 and 4,200,000 by 2020. About 80 percent of the projected population is expected to reside in King County with about 95 percent of the King County population within the Seattle urban area.

2. Seattle's present water supply system is expected to reach its capacity by about the year 1985. The ultimate development of

the Cedar and Tolt watersheds (580 mgd) will be exceeded by the year 2007.

3. A need for storage in North or Middle Fork reservoirs to meet future M&I water demands in the Seattle urban area is foreseen. By the year 2020, annual storage to yield 58,000 acre-feet (80 mgd) of supplemental water will be required.

4. With adequate waste treatment (85 percent BOD reduction), sufficient streamflow (>165 cfs) is expected to be available in the Snoqualmie and Snohomish Rivers above tidewater to maintain dissolved oxygen (5 mg/l for passage and 7 mg/l for rearing) and temperature (70°F July-August and 57°F other months) objectives for fishlife, recreation, and general aesthetics of the stream without specific releases from the proposed North or Middle Fork reservoirs for this purpose.

5. Adequate water quality can be maintained in Snohomish River estuary by removal of settleable solids from pulp and paper mill waste effluents. Deep water disposal of untreated pulp and paper mill wastes to Port Gardner Bay is currently being investigated by the FWPCA Puget Sound Enforcement Project, and recommendations with respect to needs for additional control in this regard will be forthcoming. Regulation of fresh water inflow from Snohomish River is neither needed nor effective in the control of estuary or bay water quality.

6. The annual value of storage in the North or Middle Fork Snoqualmie reservoirs to yield 58,000 acre-feet of water for M&I purposes in the Seattle urban area is estimated to be $354,000 or $6,850 per mgd. This value is based on the capital and investment cost of least-cost alternative single-purpose reservoir construction at the North Fork site, amortized over a 100-year period at 3.125 percent, discounted from time of first need in 2005.

7. Since adequate treatment or other means of waste control can maintain water quality objectives without flow regulation, no benefit for this purpose is assignable to storage in the proposed North or Middle Fork Snoqualmie reservoirs at this time.

8. If unforeseen future development in the basin results in sustained minimum flows of less than 165 cfs, the adverse effects on water quality should be considered in evaluating the benefits of the proposed water withdrawals.

III. PROJECT DESCRIPTION

A. LOCATION

The projects considered in this report are located on the North and Middle Forks of the Snoqualmie River Fork of the Snohomish River in northwestern Washington. Drainage area above the North Fork Project site is approximately 32 square miles. The drainage area above the Middle Fork Project site is about 154 square miles. Average annual runoff at the North and Middle Fork sites is approximately 350,000 and 850,000 acre-feet, respectively.

The Snohomish River drainage basin encompasses a total area of 1,825 square miles in northeastern King County and southern Snohomish County. The main stem, 22 miles long, is formed at the confluence of the Skykomish River (drainage area, 843 square miles) and the Snoqualmie River (drainage area, 688 square miles). Headwaters of both rivers are located in the Cascade Mountains. The Snoqualmie River flows in a northwesterly direction to the Snohomish River at the town of Monroe; the Skykomish River flows in more of a westerly direction to the Snohomish River (see FIGURE 1, Location Map, back cover).

B. PROPOSED PROJECT

As shown in FIGURE 1, Location Map (inside back cover), the Corps of Engineers' proposed North Fork Project is located about ten miles east of Carnation at about River Mile 12. The main reservoir, as proposed, would have a total storage capacity of 155,000 acre-feet, of which 140,000 acre-feet would be usable for flood control, water supply, power generation, fishery enhancement and recreation. Also included in the project is the installation of a 3,800 acre-foot re-regulating reservoir and powerhouse six miles downstream from the main dam.

Also shown in FIGURE 1, the proposed Middle Fork Project is located at River Mile 10 on the Middle Fork of the Snoqualmie River. The reservoir would have a total storage capacity of 129,000 acre-feet of which 120,000 acre-feet would be usable for flood control and recreation purposes.

As part of the Middle Fork Project, it is planned to stabilize a slide area in the Taylor River drainage. This slide area, upstream from the proposed dam and reservoir, has long been a source of silt carried by the Middle Fork. Success of the stabilization project should greatly improve the quality of Middle Fork waters.

The proposed North Fork Project would be operated for flood control purposes from November 1 to March 1 of each year and for recreational purposes during the summer. The project would provide a minimum release of 225 cfs which would serve to enhance the fishery and would allow for municipal and industrial water supply, when needed.

Under the proposed reservoir operation schedules, the proposed Middle Fork reservoir would be operated for flood control from November 1 to March 1 of each year and for recreation during the summer months with reservoir drawdown being held to ten feet. Minimum release from the project would be 50 cfs.

IV. STUDY AREA DESCRIPTION

A. LOCATION AND BOUNDARIES

The study area is the drainage area of the Snoqualmie River, the main stem of the Snohomish River, and the area lying west of the drainage to the Snoqualmie in the vicinity of Seattle in King and Snohomish Counties. The Skykomish River drainage will be discussed in another report in connection with the Corps of Engineers' Sultan Project investigation.

For purposes of this report, discussion regarding water supply is concerned with the Seattle urban area.

The economic base study area is comprised of King and Snohomish Counties, Washington.

The areas and stream reaches examined for water quality control purposes are the North and Middle Forks of the Snoqualmie River, the main stem of the Snoqualmie to its confluence with the Skykomish River and the Snohomish River throughout its length.

B. PHYSCIAL FEATURES

1. Geology and Soils

The Cascade Mountains are a north-south range marked by strong structural elements trending northwest-southeast. The rocks are a very complex assemblance of Cretaceous sediments, Miocene extrusives and intrusives with many older sediments and extrusives highly metamorphosed. The stream valleys were occupied by valley glaciers during the early Pleistocene age. The present bottom land deposits resulted from the action of the latest continental ice sheet. When this ice sheet occupied the Puget Trough, lower portions of valleys extending westerly from the Cascade Mountains were blocked. The rivers were dammed by glacial moraines, forming large valley lakes. When the glacial ice melted, the rivers again extended to the sea, draining the valley lakes and building deltas into the estuaries which have been converted to flood plains in the valley bottoms as tidewater has been pushed back to its present position.

Much of the lower basin and portions of the upper valleys are underlain by deep glacial, glaciofluvial, and alluvial deposits. The soils of the eastern mountainous portion of the basin, comprising about two-thirds of the drainage area, consist of a thin mantle of glacial debris on the slopes, with considerable amounts of glacial drift on gentler slopes and the valley bottoms. Much

of the soil is very gravelly and is not adapted to agricultural use. The soil of the western portion falls into two general classifications made by the Soil Conservation Service: Everett gravelly sandy loam and Puget silty clay.

2. Topography

Mountain peaks reaching altitudes of 6,000 and 7,000 feet are common along the eastern boundary of the drainage basin. The western portion of the basin is rolling in character, the altitude decreasing until tidal flats are reached at the mouth of the river. In its upper four miles the Snohomish River flows through a narrow valley from one half to one mile in width, bordered on each side by hills that rise to an elevation of about 500 feet. Along the lower reaches of the stream the valley is from two to three miles wide, much of it consisting of marshes and lowland. The valleys of the three forks of the Snoqualmie River are, in general, quite narrow and are flanked by rugged foothills. Below Snoqualmie Falls the valley floor spreads out and ranges from one-half to one and one-half miles in width.

3. Climate

Because of the wide variation in elevation from sea level to over 7,000 feet, the study area exhibits marked differences in climate. Mean temperatures range from 50°F at the lower elevations to 43°F in the mountains. Maximum temperatures of over 100°F at the lower elevation and a minimum of minus 17°F at Snoqualmie Pass have been recorded. Average annual precipitation varies from over 100 inches in the mountains to about 35 inches in the lower elevations. Mean annual snowfall, which is generally less than ten inches in the lowlands, reaches 458 inches at Stampede Pass and 420 inches at Snoqualmie Pass. Approximately 75 percent of the yearly precipitation falls during the period October through March. The growing season varies from 165 days in northern Snohomish County to 240 days in southern King County.

C. PRINCIPAL COMMUNITIES

The study area includes the northern portions of the Pacific Northwest's largest metropolitan complex--the Seattle-Everett urban area, located in King and Snohomish Counties, Washington. The non-urban areas of the Snohomish-Snoqualmie basin contain other relatively small communities, such as Duvall (350), Carnation (490), Snohomish (3,900), Snoqualmie (1,200), Snoqualmie Falls (800), and North Bend (950).

V. WATER RESOURCES of the Study Area

A. SURFACE WATER

1. Existing Water Resource Development

Water resource development in the Snohomish River Basin has been minimal in the past. The Puget Sound Power and Light Company has a run-of-the-river power plant on the upper Snoqualmie River at Snoqualmie Falls. In 1963, the city of Seattle completed construction of water supply storage facilities on the South Fork of the Tolt River, a tributary of the Snoqualmie River. In addition, some local flood control and navigation works are underway or have been completed in the lower basin.

2. Water Rights

Water rights in the Snohomish River Basin have been summarized by the Washington Department of Conservation as of 1962. This summary lists 462 applications for diversions totalling over 5,600 cfs in the entire basin. Temporary permits have been granted to 442 of these applicants in the amount of almost 1,300 cfs. Three hundred sixty-two certified or permanent water rights have been issued for approximately 600 cfs. The largest water right holders are the cities of Everett and Seattle. Everett has five rights totalling 195 cfs for municipal supply in the Sultan River, and Seattle has rights for 360 mgd in the Tolt River. Another right of 180 cfs is held by the Department of Fisheries for the operation of a fishway in the South Fork of the Skykomish River. The remaining rights are all less than 50 cfs.

Water rights in the Snoqualmie River drainage total 2,282 cfs. Applications account for 1,792 cfs of this amount with temporary permits and certified or permanent water rights accounting for 394 and 95 cfs, respectively. Water rights for the Snoqualmie River drainage are shown below.

Stream	Application cfs	Permits cfs	Certified cfs
Main Stem	831.03	373.43	76.68
South Fork	11.88	11.88	10.48
Middle Fork	6.60	6.59	5.33
North Fork	942.58	2.58	2.58
Totals	1,792.09	394.48	95.07

3. Streamflow Frequency Analysis

The Snohomish River usually has two high water periods each year. One, caused by heavy precipitation, occurs in the late fall or winter months and the other, caused by melting snow, occurs in late spring. Low flows usually occur in the months of August or September with a second low-flow period occurring in early spring.

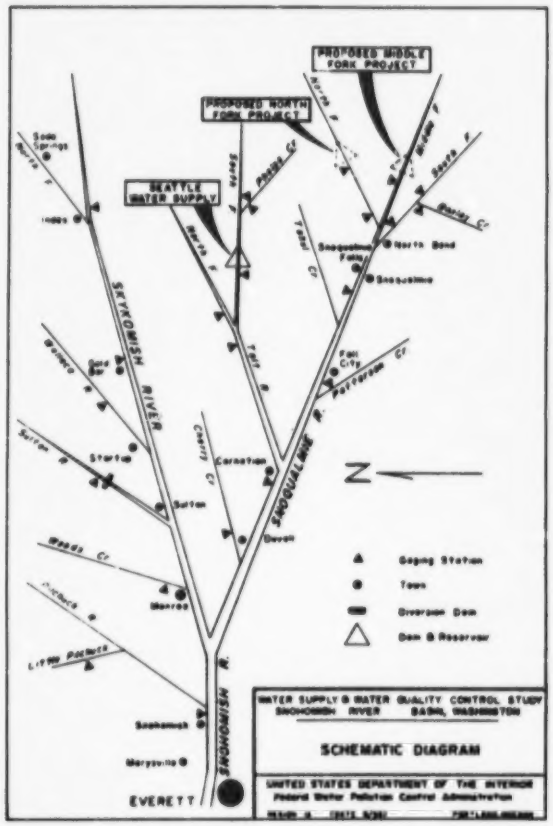

FIGURE 2

More than 20 stream gaging stations are currently operating in the Snohomish River Basin with some records having been started as early as 1898 (see Schematic Diagram, FIGURE 2). Although a station is located near the mouth of the Snohomish River at the town of Snohomish, tidal fluctuations make it impractical to compute flows below 10,000 cfs. In the Snoqualmie River drainage, the best indicator of discharge is the station located near the town of Carnation. Drainage area above this station is approximately 600 square miles. Records at this station for the period of record 1928 through 1958 were analyzed in the determination of the once-in-ten year low flow.

During this period of record, the average discharge at this station was 3,777 cfs. A low-flow frequency analysis at this location was performed using mean monthly flows for the 31 years of record (1928-1958). The annual mean low flows that may be expected to occur at this station for recurrence intervals of 5, 10, and 20 years are 3,091 cfs, 2,810 cfs and 2,400 cfs, respectively. The monthly distribution of these low flows is shown in TABLE V-1.

TABLE V-1
LOW FLOW FREQUENCY DISTRIBUTION--SNOQUALMIE RIVER NEAR CARNATION
Flows in Cubic Feet per Second

Month	Percent of Annual Mean	Recurrence Interval 1/5 Year	1/10 Year	1/20 Year
January	133	4,110	3,740	3,190
February	111	3,440	3,120	2,660
March	104	3,220	2,920	2,500
April	120	3,710	3,380	2,880
May	147	4,550	4,130	3,530
June	129	3,990	3,630	3,100
July	60.3	1,868	1,695	1,446
August	25	773	703	600
September	25.3	782	712	607
October	76.8	2,376	2,160	1,840
November	118	3,650	3,320	2,830
December	150	4,640	4,220	3,600
Annual Mean		3,091	2,810	2,400

4. Quality of Water Available

Quality of surface waters of the Snohomish River Basin has been measured on a routine basis since July 1960 as a part of a cooperative State-Federal basic data program. This program is conducted by the Washington Department of Conservation, the Washington Pollution Control Commission, and the U. S. Geological Survey. Sampling was initiated on the Snoqualmie River at Snoqualmie in July 1959, on the Tolt River at Carnation in 1960, and on the Snohomish River at Snohomish in 1959.

Selected water quality data for three stations in the Snohomish River Basin are presented in Appendix A, TABLE A-1.

Phosphate concentrations are generally below the threshold limit (>0.01 mg/1) for stimulation of aquatic organisms. Nitrate concentrations are usually near or slightly above the limit (>0.3 mg/1). The over-all mineral quality, however, is adequate for M&I uses.

MPN values in the Snohomish River at Snohomish have been recorded as high as 24,000 coliforms per 100 ml. Such high values make the river undesirable for swimming (>1,000 coliforms per 100 ml) or as a raw water supply (>5,000 coliforms per 100 ml) for treatment by conventional methods for municipal and food processing purposes. Coliform counts in the Tolt River at Carnation are considerably lower.

Based on water temperature data recorded for the Snohomish River at Snohomish from July 1959 to June 1960, maximum daily temperatures, occurring in August, reach 70°F. At the Tolt River station recorded temperatures have reached levels as high as 74°F.

B. GROUNDWATER

Limited data on the quality of groundwater in the basin indicate water generally low in dissolved solids, soft to moderately hard, and free from color or odor. Hardness of the waters taken from alluvial materials is around 50 mg/1 and that taken from deeper sands and gravels varies from about 15 mg/1 to 150 mg/1. Salinity of groundwater is generally less than 15 mg/1 of chloride except for wells in the lower flood plain and delta regions where brackish waters are the rule. The most common objectionable constituent in groundwater is iron. Iron content generally decreases with depth and is found almost universally in areas underlain with peaty alluvial materials. Iron concentrations as high as 9 mg/1 have been found in many well waters. Water quality data for selected wells in King and Snohomish Counties are presented in Appendix A, TABLE A-2.

VI. THE ECONOMY

A. GENERAL

The demand for water for municipal and industrial purposes, and the amount and character of waste waters resulting from such uses, are determined largely by the activities associated with a region's economic base. The purpose of this section is to present economic and demographic data to be used as a basis for projecting the needs for water for municipal and industrial purposes and for estimating the future amounts and types of waste and land drainage material that may be expected to occur in the Central Puget Sound Area with the expanded development anticipated in the future.

B. PRESENT

1. Economic Activities

King and Snohomish Counties, referred to in this report as the Central Puget Sound Area, include the Seattle-Everett urban center, the largest population cluster in the Pacific Northwest. Seattle is the metropolitan service center for a large region comprising most of western Washington and parts of eastern Washington. Important transportation service industries are associated with the Port of Seattle. The manufacturing sector is dominated by the Boeing Company, with substantial manufacturing employment also in pulp and paper and lumber and wood products.

In the King and Snohomish two-county area, the total labor force in 1960 was 451,700, of which 116,800 were employed in manufacturing. About half of all manufacturing employment is in transportation equipment, the classification which includes the Boeing Company. The degree of specialization in this class of

manufacturing increased markedly during the 1950-60 decade. As is shown in TABLE VI-1. 29 percent of all manufacturing employment was in this category as of April 1, 1950, and 48 percent as of April 1, 1960.

TABLE VI-1

EMPLOYMENT, BY INDUSTRY, KING AND SNOHOMISH COUNTIES

(Employment in thousands)

Industry	1960 Employment			1950 Empl.	Change in Employ't 1950 - 1960
	King Co.	Snoho-mish Co.	King-Snoho-mish Cos.	King-Snoho-mish Cos.	2 Cos.
Agriculture	4.4	2.5	7.1	9.4	-2.3
Forestry and fisheries	1.0	.3	1.3	2.4	-1.1
Mining	.4	.1	.5	.9	- .4
Manufacturing, Total	100.4	16.4	116.8	67.7	+ 49.1
Lumber, wood prod., fun. fix.	5.9	5.5	11.4	13.0	-1.6
Primary metals	2.5	.2	2.7	2.9	- .2
Fabricated metals	5.2	.6	5.8	3.5	+2.3
Machinery, non-electric	3.7	.6	4.3	2.9	+1.4
Electrical machinery	2.6	.3	2.7	.8	+1.9
Motor vehicles, equip.	2.0	.1	2.1	1.1	+1.0
Other transp., (air, water, rail)	52.8	2.8	55.6	19.6	+ 36.0
Other durables	4.1	.7	4.8	2.9	+1.9
Food and kindred	8.8	1.3 [a]	10.1	8.1	+2.0
Textiles	.3	- [a]	.3	.4	- .1
Apparel	2.4	.1	2.5	1.9	+ .6
Printing and publishing	6.3	.9	7.1	5.2	+1.9
Chemicals	1.5	.1	1.6	1.4	+ .2
Other non-dur., and misc. [b]	2.5	3.3	5.8	4.0	+1.8
Construction	20.7	4.7	25.4	23.1	+2.3
Transportation, Total	20.9	2.7	23.6	23.3	+ .3
R. R. Transportation	4.2	.8	5.0	6.3	-1.3
Trucking, warehousing	5.2	.7	5.9	4.4	+1.5
Other (air, water transp.)	11.5	1.2	12.7	12.6	+ .1
Communications, Utilities	9.9	1.7	11.6	9.8	+1.8
Wholesale trade	19.1	2.0	21.1	16.8	+4.3
Retail trade	58.6	9.5	68.1	58.6	+9.5
Finan., Insur., Real Est.	21.6	2.1	23.5	17.4	+6.1
Busin., & Repair Services	9.7	1.4	11.1	9.9	+1.2
Personal Services [c]	21.7	3.5	25.2	23.2	+2.0
Education	30.6	3.1	33.7	12.9	+ 10.8
Professional & Related Serv. [d]	27.2	3.5	30.7	19.2	+ 11.5
Public Administration	16.6	2.2	18.8	20.0	-1.2
Industry not reported	13.9	1.5	15.4	4.3	+ 11.1
Total Employed, civilian	362.7	57.2	419.9	318.9	+101.0
Unemployed	21.2	4.5	25.7	25.5	+0.2
Military	4.7	1.4	6.1	10.0	-3.9
TOTAL LABOR FORCE	388.6	63.1	451.7	354.4	+ 97.3

a/ Less than 50 persons.
b/ Includes paper, pulp, petroleum refining, rubber and leather products.
c/ Includes private household workers, hotel and lodging places, and other personal services, and entertainment and recreation.
d/ Includes hospitals, welfare and nonprofit organizations, medical and related, and other professional services.
Source: U. S. Census of Population

During the 1950-60 decade, 49,000 new jobs were established in manufacturing, and 36 000 of those were in transportation equipment, principally at the Boeing Company. Modest increases in other manufacturing categories were, to some degree, related to production of material for Boeing, indicating the company's influence on the area's economic base.

The dominance of transportation equipment manufacturing in the area's economic base can also be seen in TABLE VI-2. More than 12 percent of the entire labor force is in this category, whereas in the United States as a whole, the comparable figure is only 1.4 percent. The percentage of the total labor force in all types of manufacturing was about the same in the King-Snohomish two-county area as in the United States. The only other manufacturing category in which the two-county area has any degree of specialization, relative to the United States as a whole, is lumber and wood products. There are, of course, specializations in terms of smaller classifications than those in TABLE VI-2. For example, pulp and paper manufacturing, located at Everett, is an important specialization of the two-county area, but this activity is classed with "other non-durables" (following the procedure of the U. S. Census Bureau), and in that classification as a whole, employment in the two-county area is below the national average.

TABLE VI-2
PERCENTAGE DISTRIBUTION OF EMPLOYMENT, BY INDUSTRY
KING AND SNOHOMISH COUNTIES

Industry	King + Snohomish Co's. 1950	1960	U.S. 1960
Agriculture	3.7	1.6	6.1
Forestry and Fisheries	.7	.3	.1
Mining	.2	.1	.9
Manufacturing, Total	19.1	25.9	25.1
Lumber & wood prod. (ind., Furn., Fix)	3.7	2.5	1.5
Primary metals	.8	.6	1.8
Fabricated metals	1.0	1.3	1.8
Machinery, non-electric	.8	.9	2.3
Electrical machinery	.2	.6	2.1
Motor vehicles, equip.	.3	.5	1.2
Other transp., eq.(air, water, rail)	5.6	12.3	1.4
Other durables	.8	1.1	2.0
Food and kindred	2.3	2.2	2.6
Textiles	.1	.1	1.4
Apparel	.5	.6	1.7
Printing and publishing	1.5	1.6	1.6
Chemicals	.4	.3	1.2
Other non-dur., and misc. a/	1.1	1.3	2.5
Construction	6.5	5.6	5.5
Transportation, Total	6.6	5.2	3.9
R.R. Transportation	1.8	1.1	1.3
Trucking, warehousing	1.2	1.3	1.3
Other (air, water transp.)	3.6	2.8	1.3
Communications, Utilities	2.8	2.6	2.5
Wholesale Trade	4.7	4.7	3.2
Retail Trade	16.5	14.2	13.7
Finan., Insur., Real Est.	4.9	5.2	3.9
Busin., & Repair Services	2.8	2.4	2.3
Personal Services b/	6.6	5.6	6.2
Education	3.7	5.2	4.8
Professional and related serv. c/	5.4	6.8	6.0
Public Administration	5.6	4.2	4.6
Industry not reported	1.2	3.4	3.7
Total Employed, Civilian	90.0	93.0	82.5
Unemployed	7.2	5.7	5.0
Military	2.8	1.3	2.5
TOTAL LABOR FORCE	100.0	100.0	100.0

a/ Includes paper, pulp, petroleum refining, rubber and leather products.
b/ Includes private household workers, hotel and lodging places, and other personal services, and entertainment and recreation.
c/ Includes hospitals, welfare and nonprofit organizations, medical and related, and other professional services.
Source: U. S. Census of Population.

Aside from manufacturing, other specializations of the two-county area include air and water transportation, wholesale trade, and financial, educational and professional services.

2. Population

The 419,900 civilian jobs itemized in TABLE VI-1 were, as of April 1, 1960, the principal economic support for a population of 1,107,200 persons in the two-county area. TABLES VI-3

TABLE VI-3
POPULATION OF COMMUNITIES IN KING COUNTY

City or Area	Population 1960	1950
PORTION OF KING COUNTY INSIDE SEATTLE URBAN AREA COMMUNITIES		
Algona	1,311	n.a.
Auburn	11,933	6,407
Beaux Arts	351	n.a.
Bellevue	12,809	n.a.
Bothell	2,237	1,019
Clyde Hill	1,871	n.a.
Des Moines	1,987	n.a.
Duvall	345	236
East Richmond	293	n.a.
Houghton	2,436	1,005
Hunts Point	428	n.a.
Issaquah	1,870	955
Kent	9,017	3,278
Kirkland	6,015	4,713
Medina	2,285	n.a.
Normandy Park	3,224	n.a.
Pacific	1,577	n.a.
Redmond	1,426	573
Renton	18,453	16,039
Seattle	557,087	467,591
Tukwila	1,804	800
Yarrow Point	786	n.a.
TOTAL IN COMMUNITIES INSIDE URBAN AREA	639,635	n.a.
OTHER POPULATION (RURAL ETC.) INSIDE URBAN AREA	265,408	n.a.
TOTAL POPULATION INSIDE URBAN AREA	904,843 a/	n.a.
PORTION OF KING COUNTY OUTSIDE SEATTLE URBAN AREA COMMUNITIES		
Black Diamond	1,026	n.a.
Carnation	490	n.a.
Enumclaw	3,269	2,789
North Bend	945	787
Skykomish	386	497
Snoqualmie	1,216	806
TOTAL IN COMMUNITIES OUTSIDE URBAN AREA	7,332	n.a.
OTHER POPULATION (RURAL, ETC.) OUTSIDE URBAN AREA	22,850	n.a.
TOTAL POPULATION OUTSIDE URBAN AREA	30,171	n.a.
TOTAL POPULATION, KING COUNTY	935,014	732,992

a/ From preliminary, unpublished material by Puget Sound Regional Transportation Study.

TABLE VI-4
POPULATION OF COMMUNITIES IN SNOHOMISH COUNTY

City or Area	Population 1960	1950
PORTION OF SNOHOMISH COUNTY INSIDE URBAN AREA COMMUNITIES		
Beverly Park (unincr.)	1,950	n.a.
Edmonds	8,016	2,057
Everett	40,304	33,849
Fairmont (unincr.)	1,227	n.a.
Intercity (unincr.)	1,475	n.a.
Lake Stevens (unincr.)	1,538	n.a.
Lowell (unincr.)	1,086	n.a.
Lynnwood	7,207	n.a.
Marysville	3,117	2,259
Mountlake Terrace	9,122	n.a.
Mukilteo	1,176	826
Pinehurst (unincr.)	3,989	n.a.
Shoultes (unincr.)	3,159	n.a.
Snohomish	3,894	3,094
Woodway	713	n.a.
TOTAL IN COMMUNITIES INSIDE URBAN AREA	87,925	n.a.
OTHER POPULATION (RURAL ETC.) INSIDE URBAN AREA	49,944	n.a.
TOTAL POPULATION INSIDE URBAN AREA	137,869 a/	n.a.
PORTION OF SNOHOMISH COUNTY OUTSIDE URBAN AREA COMMUNITIES		
Arlington	2,025	1,635
Darrington	1,272	921
East Stanwood	477	378
Gold Bar	315	305
Granite Falls	599	635
Index	158	211
Monroe	1,901	1,556
Stanwood	646	710
Sultan	821	814
TOTAL IN COMMUNITIES OUTSIDE URBAN AREA	8,214	n.a.
OTHER POPULATION (RURAL ETC.) OUTSIDE URBAN AREA	26,116	n.a.
TOTAL POPULATION OUTSIDE URBAN AREA	34,330 a/	n.a.
TOTAL POPULATION, SNOHOMISH COUNTY	171,199	111,580

a/ From preliminary, unpublished material by Puget Sound Regional Transportation Study.

and VI-4 show that in 1960, about 97 percent of the total King County population was within urban areas while for Snohomish County, 80 percent was within urban areas.

C. PROJECTED ECONOMIC BASE AND POPULATION

1. Factors Influencing Future Growth

The future growth of the Central Puget Sound Area depends upon the further development of industry which is now the foundation of the economic base. Future production in transportation equipment manufacturing, the most important industry group in terms of total employment, depends largely on obtaining military contracts and commercial aircraft orders

by the Boeing Company. The record of this company suggests that average employment in this category during the study period will not decrease, except for short-run production adjustments, and may increase substantially.

The timber resource available for processing may continue at about the present level, with improved utilization and management offsetting the loss of acreage. However, the use of the basic resource is expected to alter, with a decrease in sawed lumber and increases in plywood, particle board, and pulp and paper manufacturing.

Employment in transportation services, especially in connection with the Port of Seattle, should increase in the future as well as employment in the other service industries which are now an important part of the economic base, particularly wholesale trade, finance, professional services, and education. Service industry employment related to tourism is also expected to become an increasingly important part of the economic base in the future.

2. Projected Industrial Activity and Employment

Because it has been possible in this study to adopt the population projections developed by the Puget Sound Regional Transportation Study, it has not been necessary to develop estimates of future employment by major industry group in order to derive population figures from the projected labor force. However, because of this study's orientation towards problems of water supply and pollution control, some analysis must be made of the outlook for future production in those industries which have important impact on the water resource. These industries are, generally, food processing, pulp manufacturing, and certain chemical manufacturing, notably petroleum refining. In the case of King and Snohomish Counties, it is not anticipated that food processing will become a significant part of the economic base, particularly since there is a trend towards locating food processing and packaging closer to agricultural production.

A major pulp producing center has developed at Everett. TABLE VI-5 shows the present pulp capacity there, which is the only location of pulp production in the King-Snohomish area.

TABLE VI-5
PULP MILL CAPACITY, KING-SNOHOMISH AREA, 1962

Mill Owner	Type of Process	Tons/24 hours
Scott Paper Company	Sulfite	850
Simpson Logging Company	Sulfate	80
Weyerhaeuser Company	Sulfite	350
Weyerhaeuser Company	Sulfate	325
Total		1,605

It has been estimated that total pulp consumption in the United States may double between 1960 and 1980, and double again between 1980 and 2000. This would represent an annual compound rate of increase of about 3.5 percent. The rate of growth in consumption of pulp per capita in the United States during the past decade suggests that an even higher rate of increase may occur. However, in the case of the mills in the King-Snohomish area, at Everett, a limiting factor on growth is the supply of raw materials for pulping. A large part of the raw material for the Everett mills comes from Snohomish and King Counties, but substantial amounts of chips are brought in from sawmills in British Columbia. In future years, this latter source is likely to diminish due to increased demand for chips by pulp mills in British Columbia. In addition, competition for the raw material in western Washington is likely to increase in the future, since the Everett mills are among 13 mills in the Puget Sound region and others at Grays Harbor and on the Columbia River. These limiting factors will be partially offset by improved timber management, and by the diversion to pulp of a share of the harvest formerly used for lumber. The mills at Everett are not new. As equipment is replaced, it seems logical to expect that somewhat larger capacities will be installed within the limits of the supply of raw materials. For purposes of this study, it is assumed that growth will average about one percent per year during 1960-80 and somewhat lower during 1980-2020. On this basis, pulp capacity at Everett would increase from about 1,600 tons per day at present to about 2,000 tons in 1980, to about 2,300 tons in 2000 and to about 2,500 tons in 2020. It is expected that all pulp capacity in the King-Snohomish area would continue to be at Everett.

Petroleum refining has not yet been established in the King-Snohomish area although there are two refineries at Anacortes (Shell and Texaco), in Skagit County, one at Ferndale (Mobile Oil Co.), in Whatcom County, and a small refinery at Tacoma. The present capacity of these four refineries is only about 60 percent of present

demand for gasoline in the Puget Sound area. But if the potential marketing area of the Puget Sound oil refineries is considered to be all of Washington and Oregon, then there is even more potential for expansion.

Furthermore, it is expected that demand for petroleum products will increase in the future, both on a per capita basis and as a result of economic and population growth. One estimate is that demand for petroleum to be used as fuel for motor vehicles will increase at 3.7 percent per year during the period 1960 to 2000 in the United States as a whole. The Puget Sound region and the Pacific Northwest as a whole are expected to exceed the national average growth rate.

In anticipation of future expansion in the Puget Sound area, Union and Richfield Oil Companies now hold large sites (1,000 or more acres each) for possible refineries near the Tulalip Indian Reservation, in Snohomish County, a few miles north of Everett, and Standard Oil of California holds a site of about 2,500 acres near Paine Field, southwest of Everett. These sites might be held for some years before any plant construction begins, but it is assumed for purposes of this study that refineries will be in operation at each of these sites by 1980. The typical size of the existing refineries in the area, except for the small one at Tacoma, is on the order of 50,000 barrels per day capacity.

It is assumed that these projected refineries in Snohomish County will be of this size. On this basis, present refinery capacity in the Puget Sound area, about 152,000 barrels per day, would be doubled by 1980.

Beyond 1980, additional growth in refinery capacity is expected to take place at existing plants. It is expected that capacity will double at each of the projected refineries (Ferndale, two at Anacortes, and three at Everett) between 1980 and 2020.

3. Projected Population

The projected population of King and Snohomish Counties, 1960 to 2020, is shown in TABLE VI-6. For purposes of this report, projections developed for the period 1960-2000 by the Puget Sound Governmental Conference have been adopted. For the period 2000 to 2020, a slightly lower rate of increase has been adopted

as a result of the increasing average population densities in the area and the anticipated decline in growth rate of U. S. population as a whole.

TABLE VI-6
PROJECTED POPULATION, KING AND SNOHOMISH COUNTIES, 1960-2020
(Population in thousands--Growth rates as percent compounded per yr.)

County	1960 Pop.	1960-80 Rate, %	1980 Pop.	1980-2000 Rate, %	2000 Pop.	2000-20 Rate, %	2020 Pop.
King	935	2.3	1,475	2.2	2,280	2.0	3,380
Snohomish	172	3.7	356	2.2	550	2.0	820

Source: Projections 1960 to 2000 from Interim Report, September 21, 1962, Puget Sound Governmental Conference. Figures beyond 2000 derived by assuming annual growth rate of 2.0% for 2000-2020.

The allocation of the projected future population of King and Snohomish Counties to the urban area and ex-urban area of each county has been based on work done by the Puget Sound Regional Transportation Study. Percentages developed by that study have been used for the period 1960-1980, and trends have been extrapolated to obtain percentages for 1980-2020. By applying these percentages to the total county populations projected in TABLE VI-6, estimates of future population in the urban and ex-urban area of each county are obtained. These are shown in TABLE VI-7.

TABLE VI-7
PROJECTED POPULATION OF KING AND SNOHOMISH COUNTIES
Inside and Outside Urban Area, 1960-2020
(population in thousands)

Area	1960	1980	2000	2020
King County:				
Urban Area	905	1,415	2,150	3,040
Ex-Urban Area	30	60	130	340
Total County	935	1,475	2,280	3,380
Snohomish County:				
Urban Area	138	293	448	655
Ex-Urban Area	34	63	102	165
Total County	172	356	550	820

VII. WATER REQUIREMENTS
Municipal & Industrial

A. HISTORIC AND PRESENT WATER USE

1. General

Water for municipal and industrial purposes in the study area is currently supplied by the city of Seattle, the city of Everett and many smaller systems developed by municipalities, water districts or associations, public utility districts, private water companies, and individual industries.

2. Seattle Urban Area

a. Existing Source Development

Chester Morse Lake (elevation 1,500 feet), a natural body of water in the upper Cedar River watershed, was developed at the turn of the century to provide 57,000 acre-feet of storage for water supply and hydroelectric power generation. The 143 square mile isolated and protected Cedar River watershed (80 percent owned by the city) was the sole source of water supply for Seattle and many of the surrounding communities until 1963 when a reservoir to provide 57,900 acre-feet of storage was completed on the South Fork of the Tolt River.

Average discharge in the Cedar River at the point of diversion is 665 cfs (430 mgd), and the transmission system into Seattle has a capacity of 220 mgd. In 1936, Seattle obtained water rights totalling 360 mgd in the North and South Forks of the Tolt River, a tributary of the Snoqualmie River. The presently developed water supply source and/or transmission capabilities of utilities serving the Seattle urban area is about 350 mgd. This includes 310 mgd for the Cedar and Tolt systems (220 mgd - Cedar, plus 90 mgd - Tolt).

b. Municipal and Industrial Water Use

Although industrial water use is an important factor in the Seattle water system, there are no extremely large water users such as pulp and paper mills or oil refineries on the Seattle system which warrant separation from the total water usage figure. The determination of the municipal per capita water usage figure was, therefore, based on total water usage in the Seattle urban area and the estimated served population, which in 1963 was approximately 809,000.

Water usage data supplied by the Seattle Water Department indicate a gradual increase in per capita demand of a gallon per year. Per capita demands have historically been as high as 150 gpd. During the last twenty-year period, however, per capita usage during recent dry years has been in the order of 145 gpd. The latter figure, therefore, was used as the base for projection of future demands. Water demands on the Seattle system for the five-year period 1959-1963 have averaged 99 mgd (113,000 acre-feet per year).

Use varies according to season and year, depending primarily on temperature and rainfall. Based on records of the Seattle Water Department, the monthly demand profile for the Seattle water system, also based on the period 1959-1963, was as shown in TABLE VII-2 (Demand Profile Percent).

B. FUTURE WATER DEMANDS

Future water needs of the Seattle urban area were projected by examining the historic use patterns of the Seattle Water Department. It is assumed that the one gallon per capita per year rate of increase for the Seattle urban area will continue through the next several decades and subsequently stabilize. On this basis, the yearly average demand by 1980 will be 165 gpcd and that for 2000 and 2020 will be 185 and 205, respectively. Applying these unit use figures to projected population for the Seattle urban area (King County urban area) shown in TABLE VI-7, the following average demands are obtained as shown in TABLE VII-1.

TABLE VII-1
PROJECTED MUNICIPAL AND INDUSTRIAL WATER DEMANDS
SEATTLE URBAN AREA

Year	Population 1,000's	M&I Average Water Demands		
		gpcd	mgd	Acre-Feet/Yr. (X 1,000)
1980	1,415	165	234	262
2000	2,150	185	398	445
2020	3,040	205	625	700

The projected monthly water demands for the Seattle urban area, based on the monthly demand profile for the period 1959-1963, are shown in TABLE VII-2.

TABLE VII-2
MONTHLY MUNICIPAL AND INDUSTRIAL WATER DEMAND FOR
THE SEATTLE URBAN AREA

Month	Demand Profile Percent	1980 MGD	1980 AF/MO 1000's	2000 MGD	2000 AF/MO 1000's	2020 MGD	2020 AF/MO 1000's
January	87	204	19.4	346	32.8	544	56.6
February	80	187	16.0	318	27.2	500	42.8
March	76	178	16.9	302	28.6	475	45.0
April	84	196	18.0	335	30.8	525	48.2
May	83	194	18.4	330	31.3	520	49.4
June	96	225	20.7	382	35.1	600	55.2
July	133	312	29.6	530	50.4	830	78.8
August	145	340	32.3	578	54.8	906	86.0
September	124	290	26.6	494	45.4	775	71.2
October	120	281	26.6	478	45.4	750	71.2
November	91	213	19.6	362	33.2	570	52.4
December	79	185	17.6	314	29.8	495	47.0

The Seattle system presently serves about 80 percent of the urban area water demands. The Seattle system is expected to serve increasing proportions of the urban area demands (80 percent in 1980, 85 percent in 2000, and 90 percent in 2020).

Those demands not satisfied by the Seattle facilities are expected to be adequately satisfied by either local community systems or by individual supplies.

C. WATER SUPPLY REQUIREMENTS

Projected water demands on the Seattle facilities are compared with ultimate development capabilities of the Cedar and Tolt sources in TABLE VII-3. It is indicated, from this analysis, that the capacity of the present system will be reached about the year 1985. The ultimate development of the Cedar and Tolt watersheds (580 mgd) would be exceeded by the year 2007, and by the year 2020 deficits as high as 236 mgd may be experienced during the month of maximum usage in August.

TABLE VII-3
FUTURE MUNICIPAL AND INDUSTRIAL WATER DEMAND AND SUPPLY
Seattle Facilities - MGD

Month	1980 Demand 1/	1980 Present Supply 2/	1980 Deficit MGD	1980 Deficit AF	2000 Demand 1/	2000 Supply No. 1	2000 Deficit MGD	2000 Deficit AF	2020 Demand 1/	2020 Supply No. 2	2020 Deficit MGD	2020 Deficit AF
January	168	310	-	-	294	400	-	-	490	580	-	-
February	150	310	-	-	270	400	-	-	450	580	-	-
March	142	310	-	-	257	400	-	-	427	580	-	-
April	157	310	-	-	285	400	-	-	473	580	-	-
May	155	310	-	-	281	400	-	-	467	580	-	-
June	180	310	-	-	325	400	-	-	540	580	-	-
July	250	310	-	-	451	400	51	4,840	748	580	168	15,900
August	272	310	-	-	493	400	73	8,220	816	580	236	22,400
September	232	310	-	-	420	400	20	1,840	697	580	117	10,700
October	224	310	-	-	407	400	7	660	675	580	95	9,000
November	170	310	-	-	308	400	-	-	514	580	-	-
December	148	310	-	-	267	400	-	-	445	580	-	-

1/ For purposes of this study, it is assumed that the Seattle facilities will supply 80% of the 1980 Urban Area demand, 85% of the 2000 Urban Area demand, and 90% of the 2020 Urban Area demand.

2/ Transmission system capabilities:

Present supply - Cedar @ 220 mgd + Tolt @ 90 mgd = 310
Supply No. 1 - Cedar @ 220 mgd + Tolt @ 180 mgd = 400
Supply No. 2 - Cedar @ 400 mgd + Tolt @ 180 mgd = 580

The remaining major streams available to meet the future needs are in the Snoqualmie River Basin immediately east of Seattle. The Corps of Engineers' project on the North Fork of the Snoqualmie River, approximately the same distance from Seattle as the present sources, affords an excellent opportunity to supply future needs. The quality of this raw water is comparable to that of the Cedar and Tolt supplies. Since the project area will be open for recreation purposes, which may contribute to bacterial contamination, water supplies drawn from the project will require treatment by conventional methods.

The city of Seattle has requested the Corps of Engineers to investigate the cost of obtaining water from the North Fork Project for future water supply purposes. The storage requirement requested by the city was to be based upon a maximum monthly (July) diversion of 100 mgd, or a total yearly requirement of 88,000 acre-feet.

The preceding comments on M&I water needs from the North Fork Project exclude consideration of the possible effects of the proposed resource development by King County Water District No. 97. The water district obtained a preliminary permit from the Federal Power Commission for investigation of the development of a reservoir site on the North Fork Snoqualmie River about one mile upstream from the proposed Corps of Engineers' site. The Water District No. 97 project, briefly, is concerned with construction of a dam and reservoir for water supply and hydropower purposes. The proposed water distribution system covers much of the Seattle-Everett urban area between Lake Washington and the Snoqualmie River. It extends from the Pierce County line on the south into the Mountlake Terrace-Lynnwood-Edmonds area of southern Snohomish County on the north.

Based on the deficits computed in TABLE VII-3, annual storage to yield 58,000 acre-feet by the year 2020 is required for water supply purposes in the Seattle urban area.

VIII. WATER QUALITY CONTROL

A. NEED FOR CONTROL

1. General

The waters of the study area are subjected to a wide range of uses. Municipal water supply for Everett, Snohomish, and a portion of the Seattle supply is obtained from surface waters of the basin. Other uses which are dependent upon quality of the waters are fisheries, wildlife, and recreation.

2. Municipal and Industrial Water Supply

Surface waters of the study area are utilized quite heavily for municipal and industrial water supply purposes. Bacteriological and chemical quality of both the Cedar and Tolt waters is considered excellent. Maintenance of high water quality has been in large part due to restriction of watershed activities to controlled logging operations. Protection of the watershed from contamination by restricting public access has made it possible to provide a safe water supply without treatment other than simple disinfection.

3. Fisheries

The Snohomish River has limited spawning habitat for anadromous fish. It is primarily a migration route for upstream and downstream migrant salmon and steelhead between the ocean and the extensive spawning and rearing areas in the upstream tributaries. The river system supports large runs of chinook and coho salmon, medium sized runs of chum salmon, small runs of pink salmon, and large runs of steelhead and sea-run cutthroat trout. Resident game fishes in the area consist of rainbow, brook, and cutthroat trout.

The tributary streams which are most important to spawning of anadromous fishes are the Pilchuck River, the Skykomish along with its North and South Forks, the Wallace River, the Snoqualmie below Snoqualmie Falls, and the Tolt River system below the points of diversion for the Seattle water supply. The North, Middle, and South Forks of the Snoqualmie River are inaccessible to anadromous fish due to the falls, but they support a resident population of rainbow trout as well as other fish.

From data supplied by the Fish and Wildlife Service, the average annual commercial catch of anadromous fish produced by the Snohomish River Basin is shown alongside. The run of chum salmon has diminished to the point that the catch has been restricted to restore the population. Sport fisherman-days spend in angling for these and other species per year are also shown alongside.

Chinook Salmon	20,000 fish
Coho Salmon	55,000 fish
Pink Salmon	125,000 fish
Chinook	3,500 days
Coho	14,000 days
Pink	16,300 days
Steelhead Trout	100,000 days
Resident Species	400,000 days

4. Wildlife

Big game found in the Snohomish River Basin include sizable populations of black-tailed deer and black bear. Fewer numbers of mountain goat occur at high elevations in the eastern end of the basin. The basin provides suitable habitat for moderate populations of pheasant, quail, partridge, grouse and band-tailed pigeon. Average annual hunter-days expended for big game in the North Fork Snoqualmie, Middle Fork Snoqualmie, and Sultan River watersheds are 6,000 to 12,000, 200, and 400 to 500, respectively. Hunting pressure for upland game particularly ring-necked pheasants is intense. Fur-bearing animals include muskrat, mink, raccoon, beaver, opossum, skunk, marten, otter, weasel, and fox. King and Snohomish Counties rank first and third, respectively, in the sale of trapping licenses in the State but because of low pelt prices, the economic value of fur animals is considered small. Because of mountainous terrain, waterfowl habitat is restricted primarily to sloughs along lower Snohomish and Snoqualmie Rivers where considerable nesting and moderate waterfowl hunting occur.

5. Recreation

Recreational activities, other than fishing and hunting, of importance to the Snohomish Basin are swimming, boating, picnicking, camping, and hiking. Although only one State park, Mt. Pilchuck, lies within the basin, there are two county recreation areas and many local picnic areas, particularly in those municipalities along major streams. Some seventeen public camp grounds are maintained by the Federal, State, and local governments and private timber companies. Although much of the above mentioned activity is not of a water-contact nature, its value is considerably enhanced by the

presence of a clean lake or stream. It is expected that initial recreational use of the proposed North and Middle Fork Project areas will be in the order of 340,000 visitor-days annually.

B. MUNICIPAL, INDUSTRIAL AND AGRICULTURAL POLLUTION

1. Present

Data on water-carried waste discharges from all significant municipal and industrial sources in the Snohomish River Basin are presented in Appendix B. Individual sources in this summary are listed in downstream sequence under the appropriate receiving watercourse. For purposes of this report, primary attention is given to the Snoqualmie River and lower Snohomish River.

The major waste discharges in the Snohomish Basin are located in the lower Snohomish River from the city of Snohomish to the mouth at Everett. Of the almost 54,000 people served by municipal sewerage in the basin, 48,000, or about 90 percent, are in the lower Snohomish drainage area. Chief sources of the industrial wastes produced in the study area are the Weyerhaeuser kraft and sulfite plants, the Simpson Lee Paper Company, and the Scott Paper Company. Other sources of organic industrial wastes are seasonal fruit and vegetable canneries and milk and meat processing plants.

The present municipal and industrial waste loads for the Snoqualmie River drainage and the Snohomish River are summarized in TABLE VIII-1.

TABLE VIII-1
PRESENT STUDY AREA WASTE LOADS
Population Equivalents (PE)

Drainage Area	Municipal		Industrial		Total	
	Raw	Discharged	Raw	Discharged	Raw	Discharged
Snoqualmie	6,400	5,040	5,300	700	11,700	5,740
Snohomish	57,000	22,400	7,329,000	7,203,000	7,386,000	7,225,500

The Snohomish River is 22 miles in length with tidal influence extending to about River Mile 18. About 90 percent of the wastes of the present sewered population and 96 percent of the present industrial waste load in the entire Snohomish Basin are discharged

to the lower 13 miles of the Snohomish River. Water quality problems have been encountered in this river reach due to these discharges. In 1960, the city of Everett constructed a sewage lagoon and interceptor sewers to eliminate discharge of untreated municipal wastes to the lower river. Partially treated industrial waste effluents from the two pulp mills continue to cause occasional sludge beds, low dissolved oxygen and toxicity problems in the estuary area. Studies by the FWPCA Puget Sound Enforcement Project currently nearing completion are designed to determine the effect of these and related problems on passage of migratory fishes through Port Gardner Bay.

In addition to the direct water-carried waste discharges discussed previously, another usually more subtle facet of water quality deterioration is related to land drainage and man's various activities in the watershed. Such essentially land-based operations as farming, road construction, logging, mining and recreation can cause quality deterioration in a number of ways. One such problem, although not man-caused, is the silt from a slide area in the Taylor River drainage, a tributary of the Middle Fork of the Snoqualmie River. It is expected that stabilization of this slide area as proposed by the Corps of Engineers will do much to reduce sediment in the stream. Other localized problems may be associated with return flows from the estimated 7,000 acres under irrigation by individual irrigators in the Snohomish Basin. For projection purposes, loads from these and other potential land drainage sources are considered to be covered in the BOD of uncontrolled urban runoff. Return flow data for other similar areas and conditions indicate BOD to be relatively minor generally resulting in less than 1.0 mg/l in the receiving stream.

In preliminary classification of lands in the Snohomish Basin, the Bureau of Reclamation considers 23,900 acres as being potentially irrigable. If some of this land is developed for project type irrigation where return flows may be of significant quantity, then quality deterioration, particularly by pesticides, nutrients and turbidity may occur in the receiving stream. Good farming practices can provide control of these effects thereby providing the equivalent of adequate treatment.

2. Future

In projecting 1980, 2000, and 2020 waste production for the Snoqualmie Basin it is expected that population and industry will grow at the same rate as the population projected for the King

County ex-urban area and that adequate treatment to at least 85 percent BOD reduction will be provided. The projected waste production together with the associated waste discharges after adequate waste treatment are shown in TABLE VIII-2.

TABLE VIII-2
PROJECTED WASTE LOADINGS FOR THE SNOQUALMIE RIVER BASIN
Population Equivalents

	Municipal		Industrial		Total	
Year	Raw	Discharged	Raw	Discharged	Raw	Discharged
1980	12,800	1,920	10,600	1,590	23,400	3,510
2000	27,600	4,150	22,900	3,440	50,500	7,590
2020	72,500	10,900	60,000	9,000	132,500	19,900

Future growth in pulp and paper manufacturing and oil refining projected for the Snohomish Basin is expected to center on salt water in the Port Gardner Bay vicinity. Population increase is also expected to center in the vicinity of Everett where the additional waste is expected to be collected and treated for discharge to Port Gardner Bay.

Projected waste loads for the pulp and paper and oil refining industries are shown in TABLE VIII-3.

TABLE VIII-3
PROJECTED PULP AND PAPER AND OIL REFINING WASTE LOADS
CENTRAL PUGET SOUND AREA

	Pulp and Paper		Oil Refining	
Year	Raw	Discharged *	Raw	Discharged *
1980	9,150,000	1,370,000	90,000	13,500
2000	10,500,000	1,575,000	125,000	18,800
2020	11,430,000	1,715,000	180,000	27,000

* Based on 85 percent BOD reduction.

C. WATER QUALITY OBJECTIVES

Water quality objectives for the various water uses to be served are discussed as follows.

1. Dissolved Oxygen

The dissolved oxygen (DO) objective for the Snoqualmie River is dependent upon anadromous fishery requirements--the use requiring the highest DO level. Other uses served at this level are recreation and aesthetic conditions.

Maintenance of 5 mg/l of dissolved oxygen would provide suitable conditions for anadromous fish passage while 7 mg/l provides adequate conditions for rearing. Spawning areas, however, require dissolved oxygen at saturation levels.

2. Temperature

Temperature requirements for the Snohomish and Snoqualmie Rivers are governed primarily by the anadromous fishery. Maximum temperatures should not exceed 70°F during July and August, to facilitate fish migration, holding and rearing; by mid-September, temperatures should not exceed 57°F to obtain optimum egg survival.

3. Bacteria

Bacterial objectives for recreation and water supply use are 1,000 MPN and 5,000 MPN, respectively. Treatment, including disinfection, is required to reduce bacterial concentrations.

D. FLOW REGULATION

Prior to 1951 a barrier to the normal migration of salmon existed in the lower Snohomish River estuary and Port Gardner Bay. The barrier consisted of oxygen-deficient water in the river mouth during periods of low flow as a result of waste discharges primarily from two large pulp mills at the river mouth. Construction of a deep water outfall in Port Gardner Bay to achieve better dilution and dispersion of untreated waste has done much to alleviate the problem. Studies by the FWPCA Puget Sound Enforcement Project currently nearing completion will assess the effectiveness of this disposal method.

Adequate water quality can be maintained in Snohomish River estuary by removal of settleable solids from pulp and paper mill waste effluents. Regulation of fresh water inflow to this area

or to Port Gardner Bay is neither needed nor effective in accomplishing the necessary control.

Computations utilizing oxygen balance techniques show that about 165 cfs will be required to receive the 2020 projected waste load (20,000 PE) and maintain minimum DO objectives for fish passage and rearing in lower Snoqualmie River. More than adequate flow without regulation is available (minimum average daily flow of record, 396 cfs, upstream near Carnation) to maintain these objectives.

It is cautioned, with regard to expected future minimum flows, that water right applications in the Snoqualmie River watershed totalling 1,792 cfs if granted and fully exercised, would completely deplete streamflows during low flow periods. Firm rights at present in the Snoqualmie Basin total 95 cfs.

The Washington State Department of Conservation, Division of Water Resources, has advised that depletions to no less than about 100 cfs, depending upon fisheries requirements, would be allowed in the lower reaches of the Snoqualmie River. For hydrologic projection and storage determination purposes of this study it is assumed that sustained depletions to less than the required 165 cfs will not take place within the study period.

If, however, future development in the basin results in sustained minimum flows of less than 165 cfs, the adverse effects on water quality should be considered in evaluating the benefits of the proposed water withdrawals.

Lack of adequate temperature data for the Snohomish River Basin precludes judgment of the possible need for temperature control or of the potential temperature effects of the proposed projects on the Snoqualmie and Snohomish Rivers. However, studies are being conducted in other basins by the FWPCA regarding the effects of impoundments on stream temperature, which may provide information at a later date applicable to the projects under study.

As foreseen at this time, adequate treatment or control of waste at the source will provide satisfactory control of water quality in the Snoqualmie and Snohomish Rivers without specific release from storage in the proposed North or Middle Fork reservoirs for this purpose.

IX. BENEFITS....Water Quality Control

A. WATER SUPPLY - MUNICIPAL AND INDUSTRIAL

A future need for storage for municipal and industrial water exists in the Snoqualmie River watershed. By the year 2020, 58,000 acre-feet (80 mgd) of annual supplemental storage will be required. Time of first need is estimated to be about the year 2005, thirty years after the assumed project completion in 1975.

For benefit computation purposes the value of this storage is considered to be equal to the cost of the least-cost, most-likely, non-Federal single-purpose alternative reservoir that could be constructed in the absence of the North and Middle Fork Snoqualmie Projects. After considering three possible alternative sites, it has been determined, based on cost data provided by the Corps of Engineers, that the most likely alternative would be a single-purpose impoundment on the North Fork Snoqualmie River.

The annual value of 58,000 acre-feet of storage in the North Fork Snoqualmie Project has been determined to be $354,000 or $6,850 per mgd. This value includes operation and maintenance costs ($50,000) and is based on a 100-year amortization period at an interest rate of 3.125 percent, discounted for 30 years (assumed project completion in 1975) from the first need in 2005. In arriving at this value the capital cost ($32,600,000) of a 73,000 acre-foot reservoir which would provide approximately the same development of available stream water at the lowest unit cost was used.

B. WATER QUALITY CONTROL

As already indicated, no requirements for storage for water quality control in the Snoqualmie or Snohomish Rivers are foreseen at this time. No apparent damage to water quality is expected to occur as a result of operations of the North Fork Snoqualmie River Project. No positive or negative benefits can be assigned to storage in or operation of the proposed project.

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APPENDIX

APPENDIX A

TABLE A-1
REPRESENTATIVE ANALYSES OF SURFACE WATERS
SNOHOMISH RIVER BASIN, WASHINGTON

Constituent	Snoqualmie River at Snoqualmie					Tolt River at Carnation					Snohomish River at Snohomish				
Date	7/8/59	7/11/61	8/15/62	11/13/63	8/10/65	11/1/61	8/15/62	11/13/63	11/23/64	8/10/65	1/15/61	1/10/62	8/25/64	7/12/65	8/10/65
Discharge, cfs	-	-	-	-	-	-	-	-	-	-	23,230	28,700	-	-	-
Silica (SiO_2), ppm	5.3	5.0	6.1	5.8	6.1	5.3	8.0	7.4	6.2	7.7	5.9	6.6	5.1	7.9	6.5
Calcium (Ca), ppm	3.5	4.5	4.5	3.5	5.6	3.0	6.5	5.0	5.0	7.6	4.0	3.0	4.0	4.4	5.6
Magnesium (Mg), ppm	0.1	0.4	0.7	0.6	0.9	0.7	1.2	1.2	1.1	1.9	0.4	0.9	1.0	0.5	1.2
Sodium (na), ppm	0.8	1.0	1.5	1.5	1.6	1.3	1.9	1.8	1.7	2.1	1.3	1.4	2.1	1.6	2.3
Potassium (K), ppm	0.3	0.2	0.6	0.3	0.4	0.3	0.4	0.3	0.3	0.3	0.4	0.5	0.5	0.4	0.6
Bicarbonate (HCO_3), ppm	12	16	18	14	21	10	26	20	20	32	14	12	19	17	24
Sulfate (SO_4), ppm	1.4	2.0	2.2	2.4	2.6	3.4	5.4	4.2	4.2	4.8	2.2	3.0	1.6	2.2	2.8
Chloride (Cl), ppm	0.8	0.5	0.5	1.0	0.8	1.0	0.8	1.2	0.8	1.0	0.5	1.0	1.0	0.8	1.2
Nitrate (NO_3), ppm	0.3	0.1	0.3	0.9	0.3	0.5	0.4	1.0	0.6	0.4	0.9	1.3	0.3	0.4	0.4
Phosphate (PO_4), ppm	0.00	.07	0.02	-	0.02	0.02	0.01	-	0.01	0.03	0.01	0.11	0.01	0.07	0.02
Dissolved Solids[1], ppm	20	27	28	24	28	29	39	35	34	39	30	29	23	26	37
Specific Conductance[2]	25	31	38	30	45	28	26	44	43	65	33	34	43	35	53
pH	6.5	7.1	7.1	6.9	6.9	6.6	7.5	7.0	7.1	7.2	6.9	6.8	7.3	7.0	6.8
Temperature	54°F	15.9°C	17.0°C	8.1°C	15.2°C	6.5°C	18.2°C	8.6°C	7.0°C	15.0°C	-	-	16.0°C	15.7°C	18.0°C
Dissolved Oxygen, ppm	10.7	9.0	9.4	10.8	9.0	11.7	9.4	10.7	12.0	9.8	-	-	9.4	9.8	8.5
MPN[3]	750	2400	4600	930	4600	-	-	36	390	430	-	-	4600	930	24,000

1/ Residue on evaporation at 180°C

2/ Micromhos at 25°C

3/ Most probable number coliform groups per 100 ml

Source: Unpublished data, Washington State Pollution Control Commission

APPENDIX A

TABLE A-2
GROUND WATER QUALITY
KING AND SNOHOMISH COUNTIES

Owner	Well Location Code	Date	Temp °F	PARTS PER MILLION: Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Nitrate (NO_3)	Ortho-Phosphate (PO_4)	Dissolved Solids 1/	Hardness (as $CaCO_3$)	Specific Conductance 2/	pH
KING COUNTY															
King County Water Dist. #64	21/4-5Q2	12/18/59	50	19	4.4	14	5.3	5.8	2.6	0.2	0.09	102	57	157	7.6
Boeing Aircraft Co.	23/4-4A1	4/19/54	56	25	0.14	-	-	314	8.4	1.0	-	872	-	1600	-
King County Water Dist. #82	24/6-4N1	4/ 3/58	48	34	1.0t	10	4.6	4.2	3.3	3.3	-	96	44	106	7.2
City of Issaquah	24/6-27Q1	8/20/51	50	17	0.07	22	3.5	7.4	1.8	0.1	-	109	69	162	8.0
Darigold Farms	24/6-28J1	8/20/51	-	22	0.01	10	3.3	5.4	1.6	3.5	-	84	38	105	7.0
Fall City Water Co.	24/7-11L1	8/20/51	-	47	1.6t	20	6.8	6.6	3.4	0.2	-	143	78	175	7.7
City of Redmond	25/5-12C1	3/24/59	40	23	0.06	10	4.7	4.9	1.1	5.6	-	82	44	116	7.3
Carnation Farms	25/7-6R1	10/ 6/60	54	27	1.1	22	9.2	22	4.2	0.0	0.58	176	93	269	8.0
Bothell Water District	26/5-5E1	8/24/51	-	47	0.03	21	8.4	8.6	4.0	0.7	-	158	87	201	7.2
City of Duvall	26/6-13D1	10/ 6/60	50	16	.11	24	5.8	32	2.2	0.8	0.47	179	84	290	8.1
SNOHOMISH COUNTY															
City of Edmonds	27/3-24Q3	12/18/59	-	36	0.00	9.5	9.4	5.9	2.1	3.3	0.21	113	62	160	7.6
Alderwood Manor Water Dist.	27/4-10N1	12/ 1/59	50	45	0.00	13	6.1	7.8	2.7	0.2	0.60	123	58	156	7.7
Snohomish County PUD #1	28/5-7G2	10/13/60	51	33	0.05	10	10	5.3	1.7	6.9	0.17	111	67	162	7.5
City of Marysville	29/5-2C1	12/18/59	48	25	0.81	18	7.5	6.1	1.3	0.2	0.69	118	76	179	7.8
Potlatch Beach Water Dist.	30/4-35R1	10/ 5/60	49	40	0.89	36	19	11	3.4	2.0	0.43	229	170	364	7.4
City of Arlington	31/5-2L1	4/27/61	48	8.5	0.08	9.0	3.5	2.2	0.7	0.7	0.00	58	37	86	7.2

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1/ Residue on evaporation at 180° C

2/ Micromhos at 25° C

Iron: Total iron concentrations are followed by a "t." All other values represent iron in solution at the time of sample collection.

Source: GROUND WATER IN WASHINGTON, ITS CHEMICAL AND PHYSICAL QUALITY, Water Supply Bulletin No. 24, Washington State Department of Conservation, 1965.

APPENDIX B

MUNICIPAL AND INDUSTRIAL WASTES INVENTORY

SNOHOMISH RIVER BASIN

Receiving Water Course & Municipality or Separately Discharging Industry	River Miles Above Mouth	1960 Population	Est. Pop. Served	Estimated PE of Waste before Treatment	Treatment Provided	Estimated PE Discharged to Watercourse	Seasonal Waste PE Raw	Seasonal Waste PE Disch.	Remarks
Snohomish-Skykomish River									
Index	51.4	158	170	170	None	170			
S. Fk. Skykomish River	50.0								
Stevens Pass Rec. Area									
Skykomish	49-8	366	X	X	No System	X			Primarily Winter Use
Grotto	49-4	X	X	X	No System	X			Unincorporated small hamlet
Ideal Cement Co.				Inorganic					
Gold Bar	40	315	X	X	No System	X			
Sultan	35	821	500	500	None	500			Grant applied for May 1966
Monroe	25	1,901	1,950	2,400	Primary	1,800			
Sky Valley Meat Co.				300	Primary	150			
State Reformatory		X	1,000	1,000	Lagoon	100			
Snoqualmie River	20.7								
S. Fk. Snoqualmie River	20-45								
Snoqualmie Pass Rec. Area	20-45-28	X	X	4,000	None	4,000			Planning Construction 1966
North Bend	20-45-2	945	900	1,200	Primary	840			
Snoqualmie	20-42	1,216	900	900	Lagoon	100			
Snoqualmie Falls		X	300	300	Primary	100			
Weyerhaeuser Co.		X	X	5,000	Pond	500			14 mgd water used on barker
Fall City	20-36	X	X	X	X	X			
Carnation	20-25	490	X	X	No System	X			
Duvall	20-14	345	X	X	No System	X			
James Wallace Meat Pkg. Co.		X	X	300	Primary	200			6 Beef 1 day/week
Pilchuck River	13.7								
Granite Falls	14-16	599	600	600	Primary	420			
Little Pilchuck River	14-9.3								
Lake Stevens	14-9-3				No System				
Berry Valley Farm Pak				Seasonal	None		5,000	5,000	June-July--50T strawberries, 20T raspberries
Snohomish	13	3,894	4,000	8,400	Lagoon	1,500	89,000	20,000	June-July
Berryland Packers Inc.		X	X	Seasonal			(3,000)	(X)	June-July
Clancy's Frozen Sticks		X	X	(1,000)	City Sewer	(X)			
Snohomish Co. Dairymens Assn.		X	X	(1,800)	City Sewer	(X)			
Evergreen Frozen Foods				Seasonal	City Sewer		(45,000)	(X)	July-September
Ferguson Canning Co.				(500)	City Sewer	(X)			
Hershey Packing Co.				Seasonal	City Sewer		(30,000)	(X)	June-August
Puyallup & Sumner Sales Co.				Seasonal	City Sewer		(2,000)	(X)	June-July
Snohomish Meat Co.				700	Septic Tank	300			
Ebey Slough	8.3								
Marysville		3,117	3,000	3,000	Lagoon	450	5,000	750	
Snohomish Co. Berry Growers		X	X	Seasonal	(Lagoon)		(2,000)	(X)	June-July, 10T strawberries
Jansha Tanning Co.		X	X	600	Lagoon	300			
Lowell	7.0	1,086	(1,000)	(1,000)	Everett Lagoon	(X)			
Simpson Lee Paper Co.		--	X	75,000	Swamp	50,000			271 T/day
Everett	3.3	40,304	41,000	45,000	Lagoon	20,000			
Foremost Dairy				(450)	City Sewer	(X)			
Scheerer Canning Co.				(450)	City Sewer	(X)			
Puget Sound By Products	2.5			1,000	None	1,000			
Federal Packing Co.	2.5			2,400	None	2,400			
Weyerhaeuser Lumber Mill	1.3			10,000	None	10,000			
Weyerhaeuser Kraft Div.				240,000	Pond	237,000			
Everett Fish Co.				600	None	600			To Steamboat Slough
Scott Paper Co.				4,740,000	Deep Water Outfall	4,740,000			Deep Water Outfall
				155,000	Clarifier	57,100			New Survey, June 1966
				125,000		125,000			Main Mill - No Treatment
Weyerhaeuser Sulfite				1,980,000		1,830,000			Deep Water Outfall
						156,000			To Inner Harbor
Boeing Assembly Plant									Under Construction 1964
Mukilteo		1,128	1,200	1,300	Primary	460			To Puget Sound
Paine Air Force Base				1,300		200			To Puget Sound

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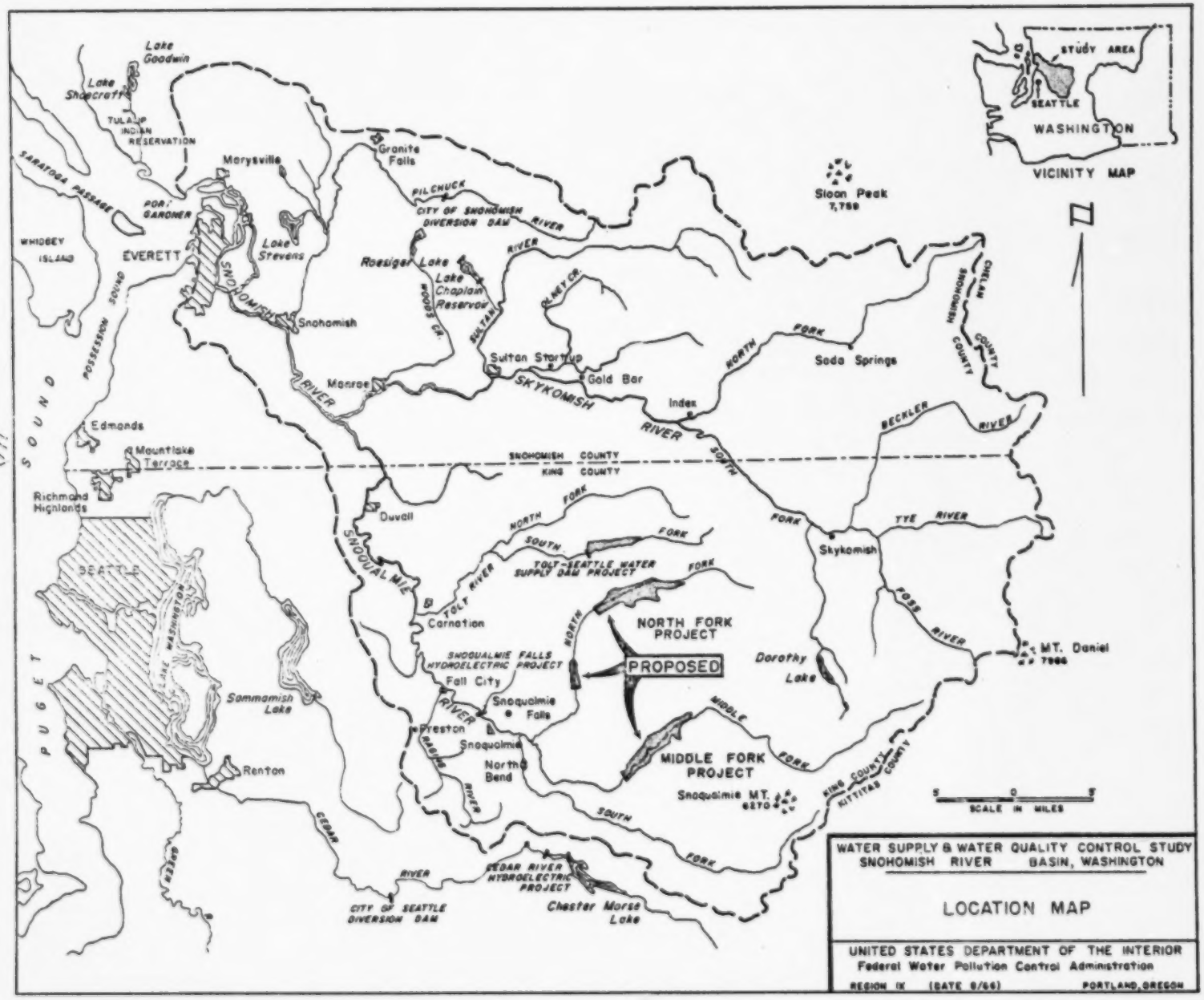

WATER SUPPLY & WATER QUALITY CONTROL STUDY
SNOHOMISH RIVER BASIN, WASHINGTON

LOCATION MAP

UNITED STATES DEPARTMENT OF THE INTERIOR
Federal Water Pollution Control Administration
REGION IX (DATE 8/66) PORTLAND, OREGON